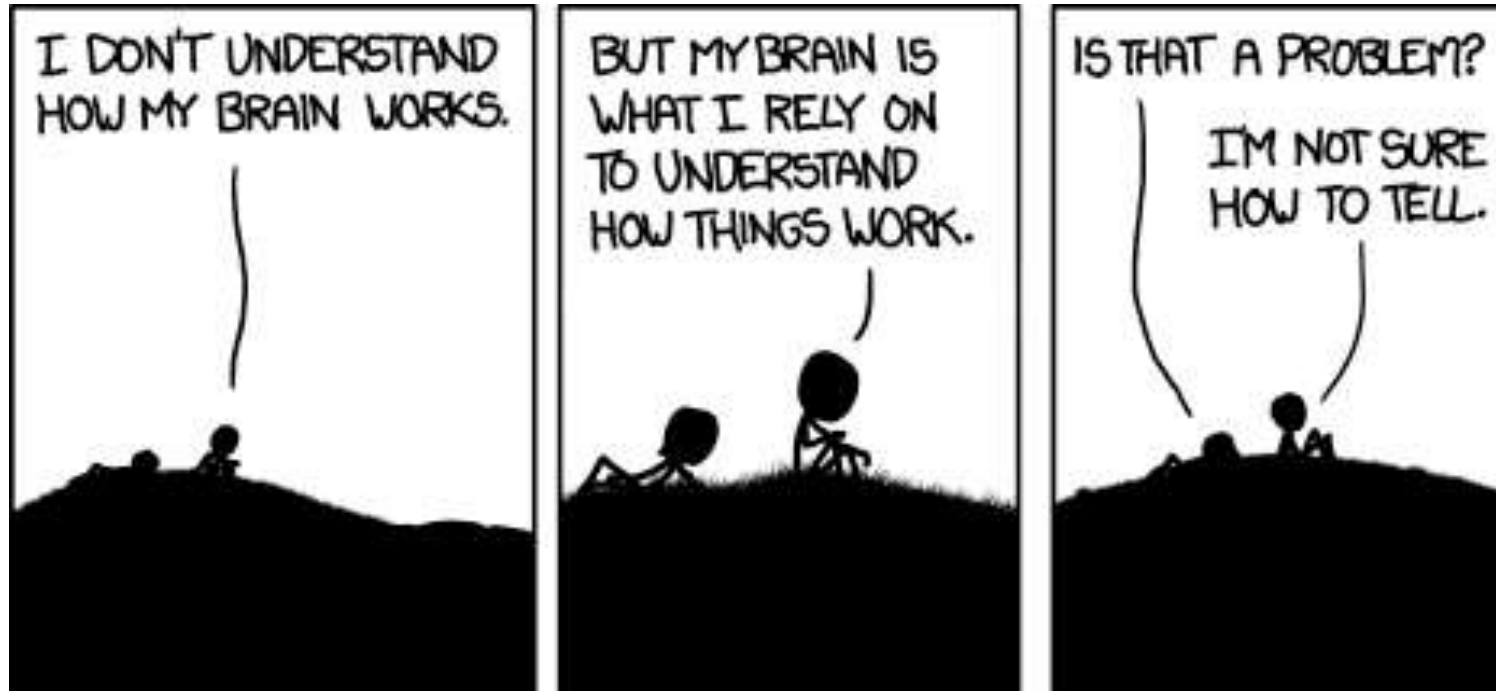
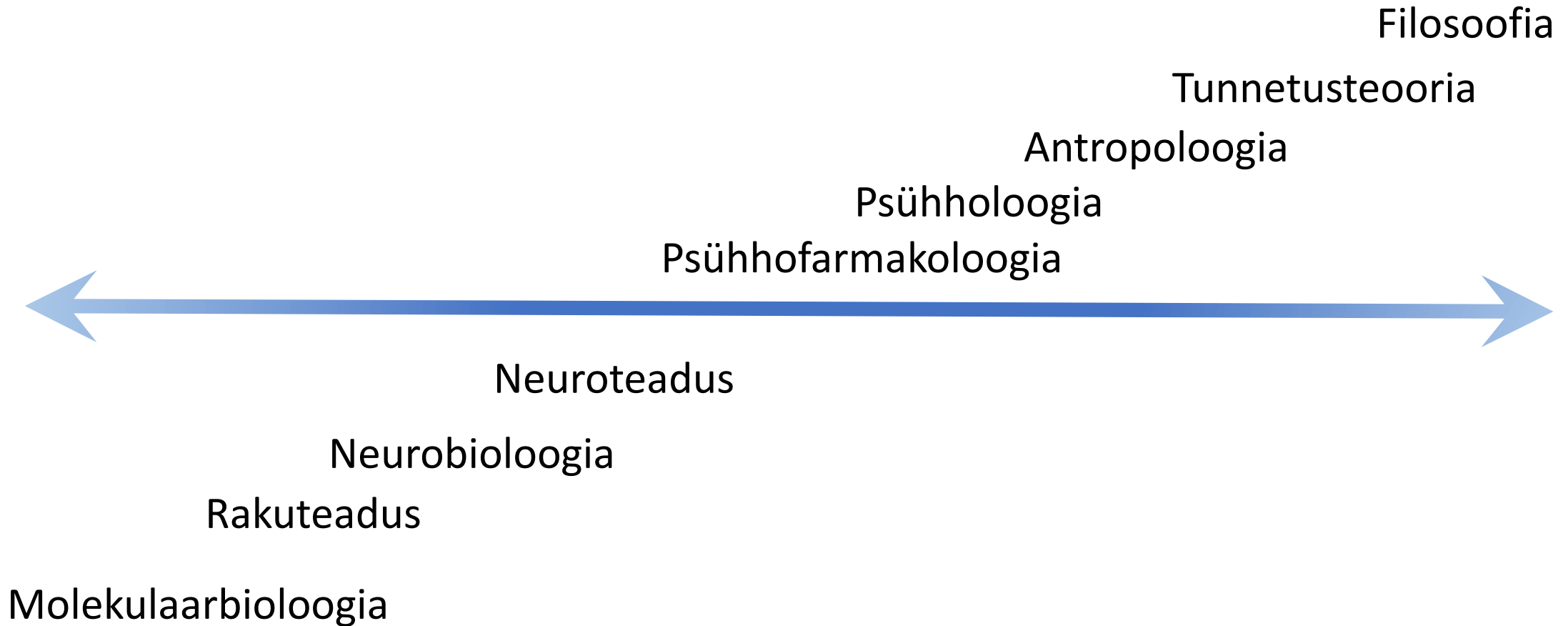


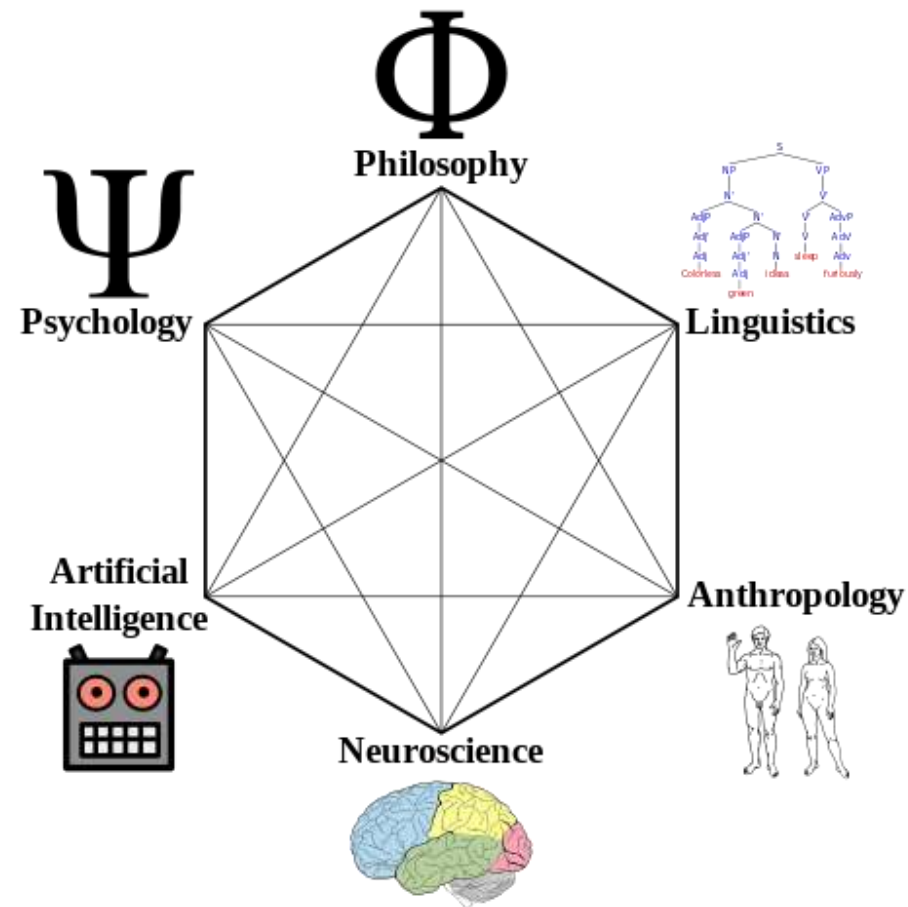
Ajuteadus



Orientatsioon: mis on ajuteadus



Tihedalt seotud mõiste: cognitive science



Orientatsioon: mis on teada ja mis ei ole?

- Päris palju on teada kõigis ajuteaduse alamvaldkondades ja teadmist tilgub pidevalt juurde
- Aga: põhiküsimuste osas ei ole mingitki arusaama ega ühtegi tõsiseltvõetavat teooriat:
kuidas mälu, emotsioonid, mõtlemine, teadvus töötavad?
- Prognoosid, et millal me mõnest põhiasjast aru saame, varieeruvad 10-20 aastast lõpmatuseni (et ei saa kunagi aru). Lähiaja optimismi ei ole.

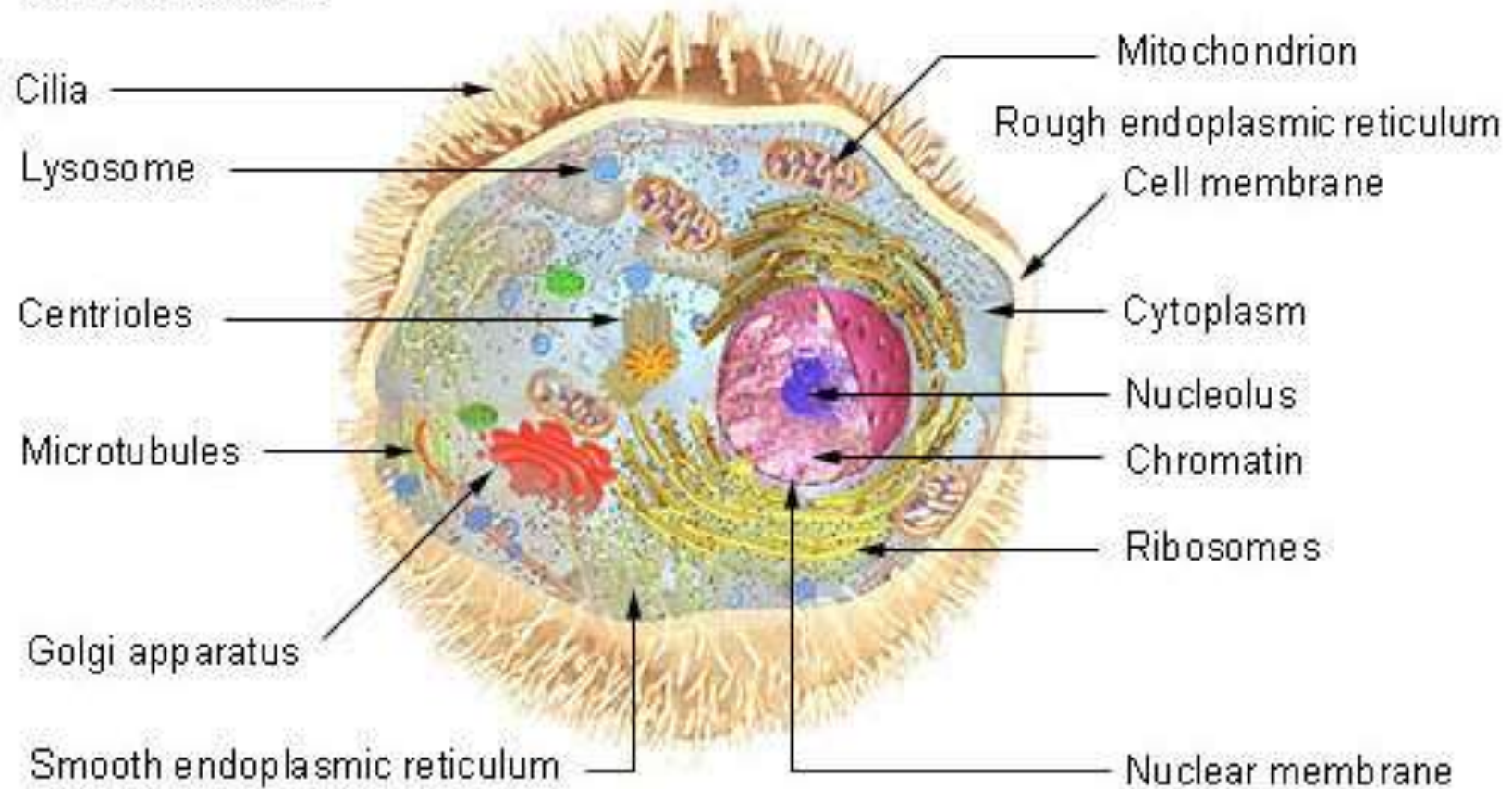
Loengu teemad

- Neuronid
- Aju funktsionaalsed osad
- Evolutsioon
- Tajude ja mõistuse teooriad
- Teadvuse teooriad

Neuronid ja nende seosed

Rakk on väga keeruline elusolend

Cell Structure



Veidi rakust

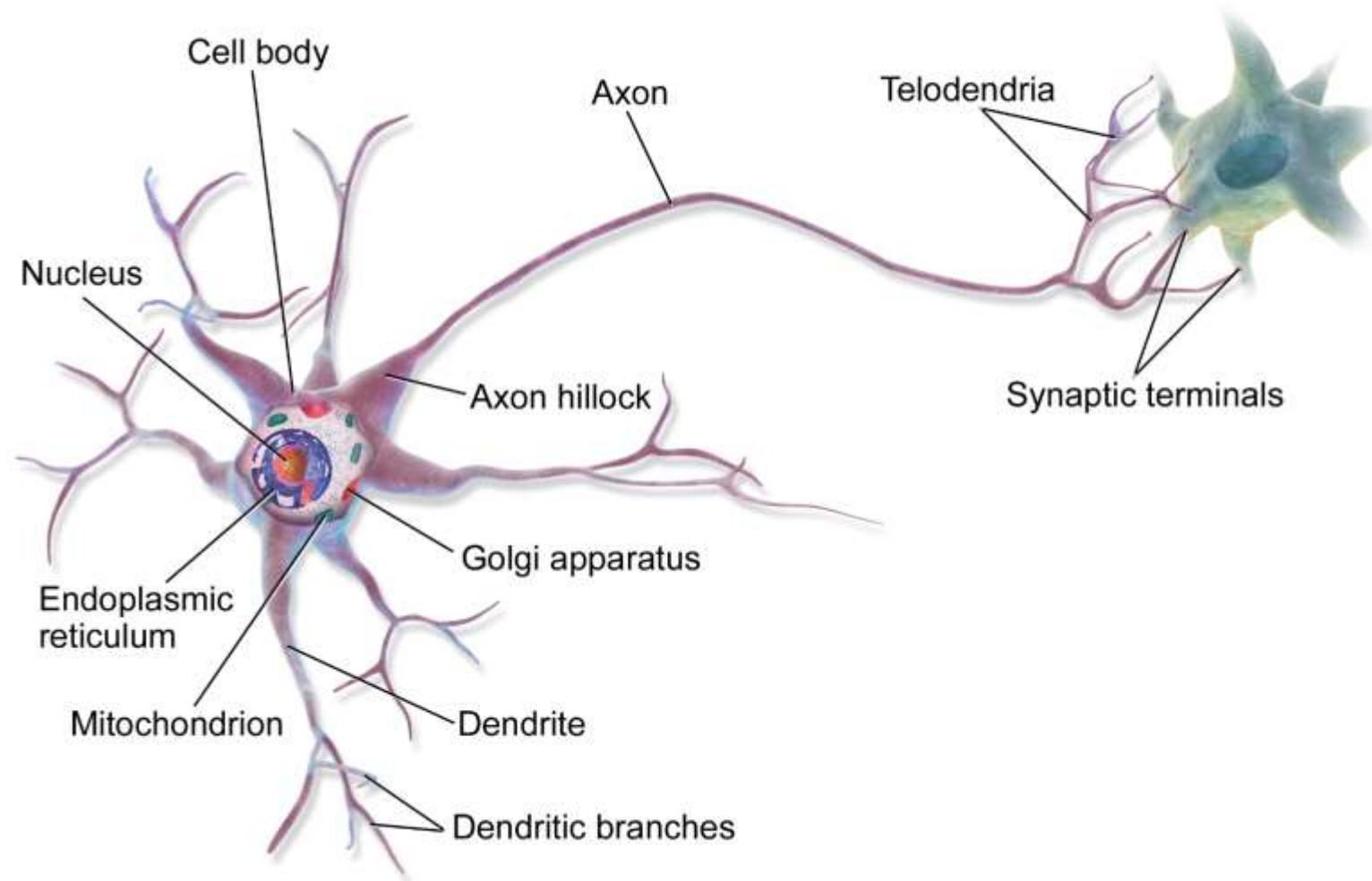
- Tekkisid ca 3.5 miljardit aastat tagasi
- Rakud paljunevad pooldumise teel: mingis mõttes rakk ei sure kunagi
- Raku sees on veel teise DNA-ga omaette „rakk“: mitokonder
- Mitokonder sisaldab mh pöörlevaid elektrimootoreid
<https://www.youtube.com/watch?v=kXpzp4RDGJI>
- DNA üksi sisaldab ca 3.4 gigabaiti andmeid

Raku sise-elu on ülikiire

Tsitaadid:

- „It turns out that molecules move unimaginably quickly due to thermal motion. A small molecule such as glucose is cruising around a cell at about **250 miles per hour**, while a large protein molecule is moving at **20 miles per hour**.“
- „As a result of all this random motion, a typical enzyme can collide with something to react with **500,000 times every second**“

Peamised rakud ajus: **neuronid**



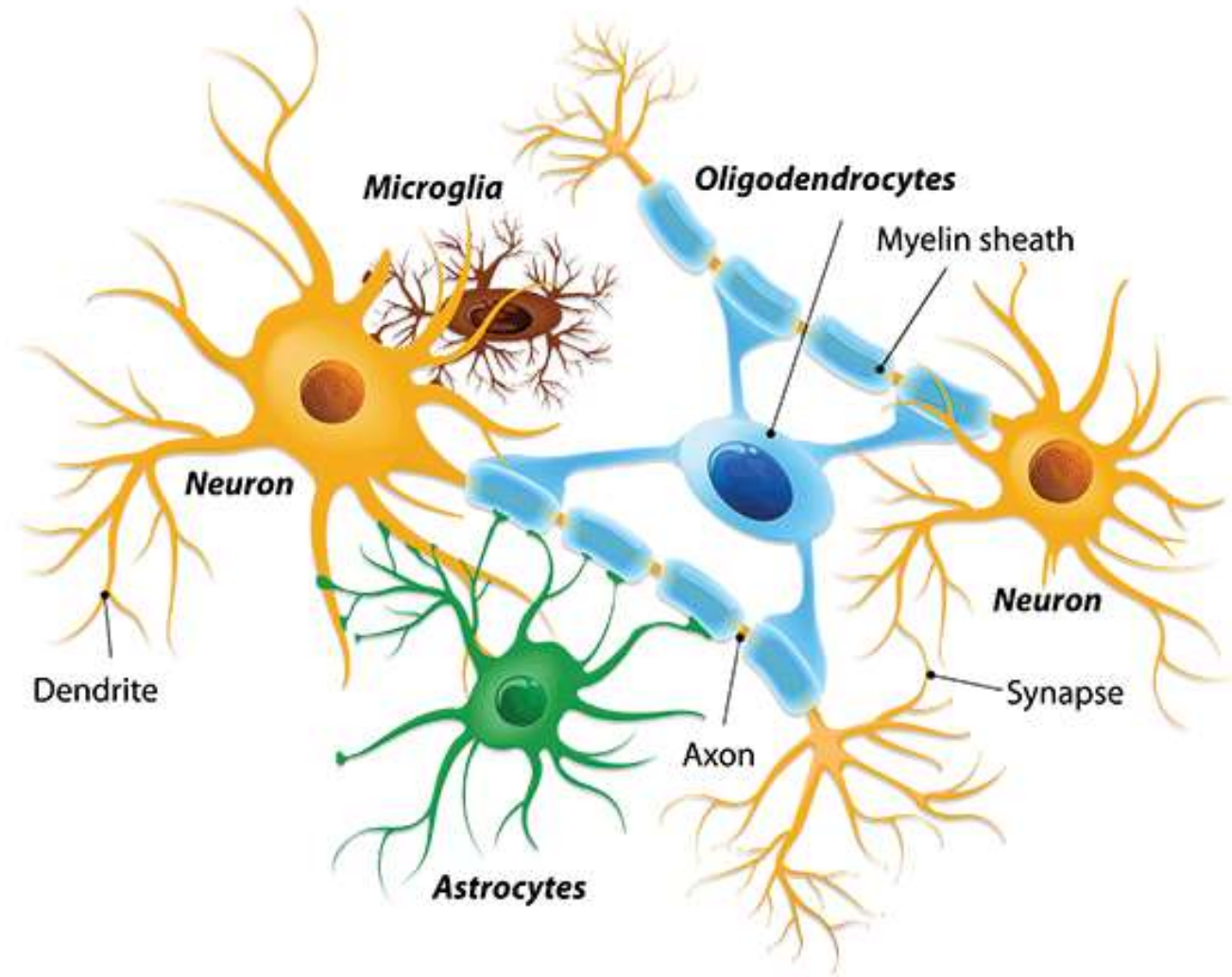
Dendriidid ja aksonid

Neuroni ühendusosad:

- **Dendriidid** (lühikesed ja palju): eeskätt (?) sisend neuronisse
- **Aksonid**: üks ja pikk (kuni meeter!): eeskätt (?) väljund
- **Sünapsid**: aksoni otsas hulk hargnevaid ühendusi teiste neuronitega

Paljud aksonid on kaetud elektrilise isolatsiooniga: müeliin

Gliarakud



Müeliin ja gliiarakud on olulised

- Müeliini hulga reguleerimine – seotud gliiarakkude tegevusega – on üks aju õppismehhanisme.
- Rohkem müeliini aksoni ümber tekitab mh kiirema signaali leviku aksonis.

Neuroneid on hulka erinevaid tüüpe

Põhitüübid on

- Sensorneuronid: keskkonna tunnetamiseks
- Motoneuronid: lihaste liigutamiseks
- Vaheneuronid: enamik aju on vaheneuronid

Igal tüübil on väga palju alamtüüpe.

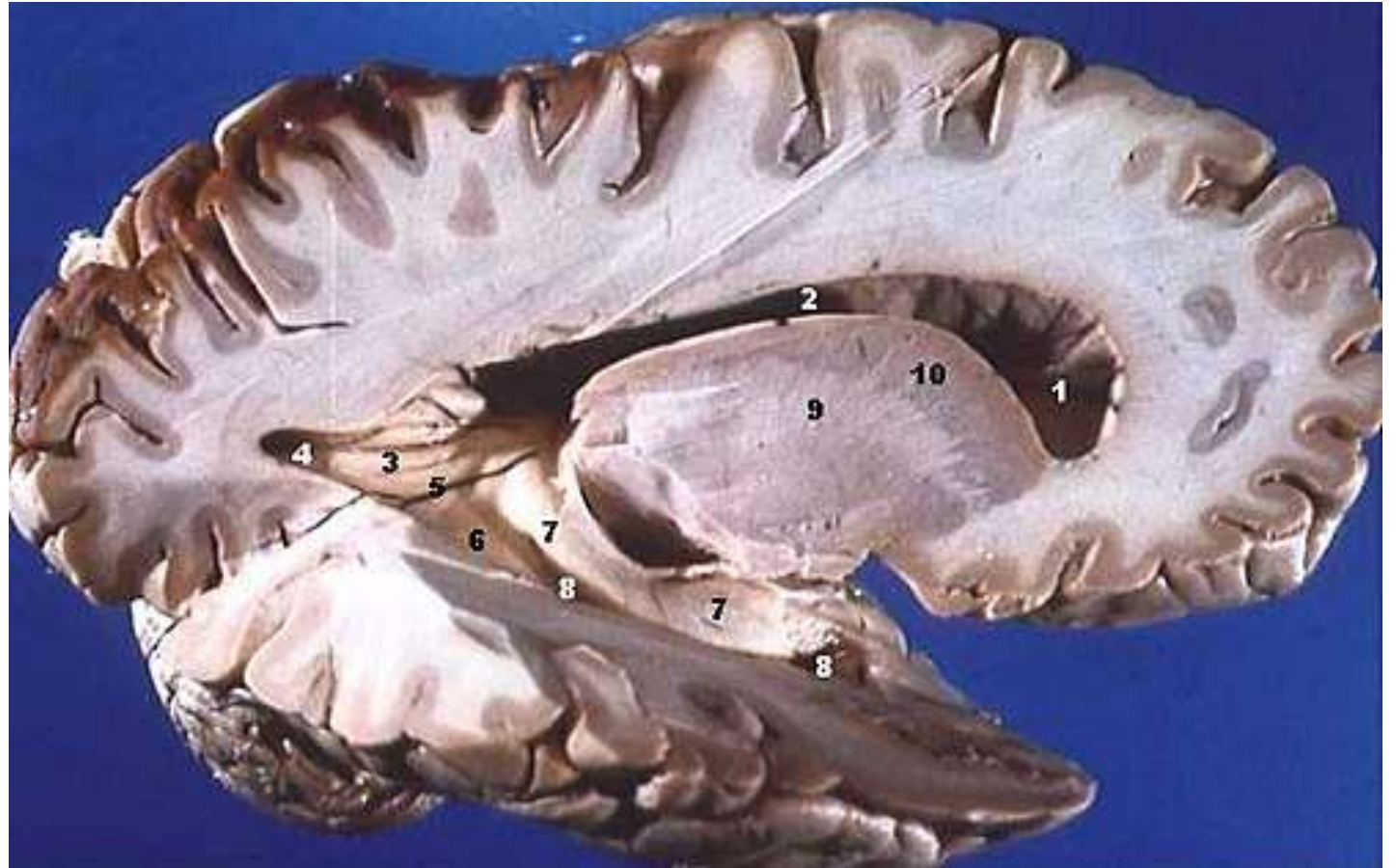
Aju kasvufaasis – ja ka hiljem - neuronid
ühenduvad naabritega

<https://www.youtube.com/watch?v=hb7tjqhfDus>

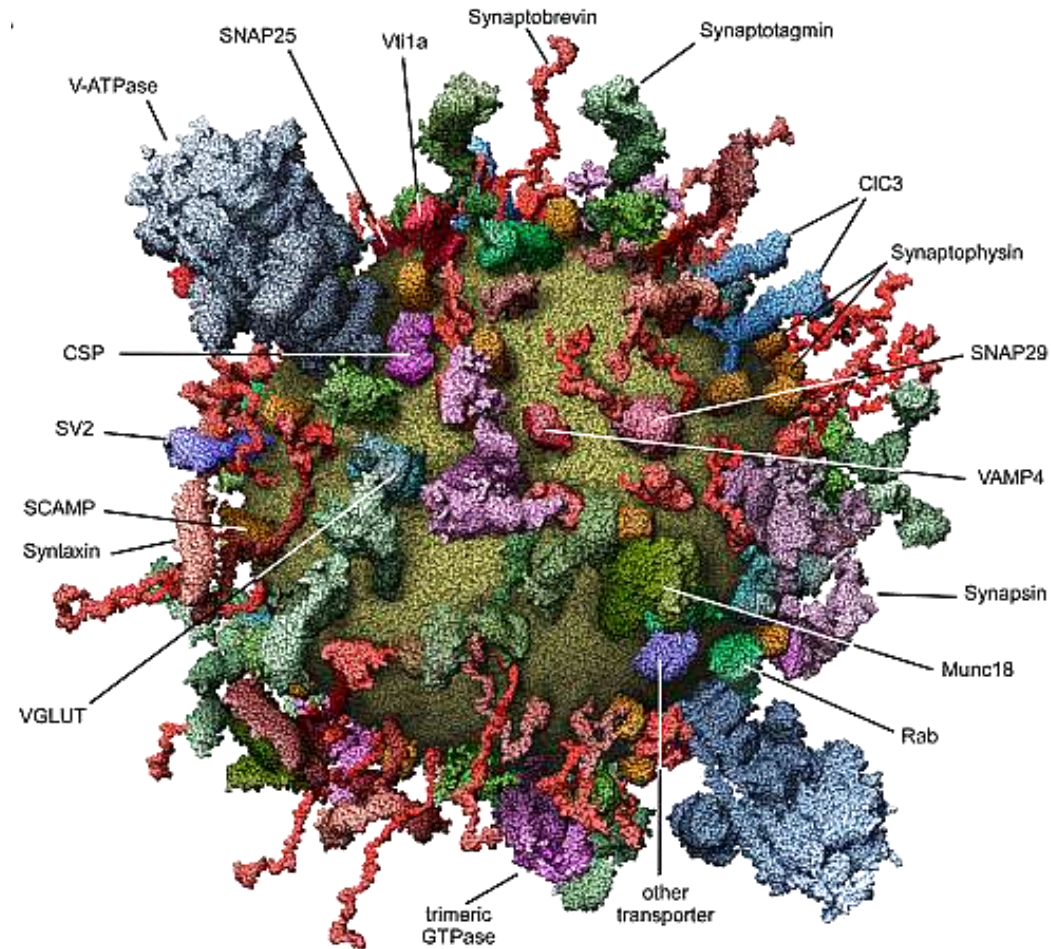
<https://www.youtube.com/watch?v=GRKmc1AfsbY>

Aju lõige: grey and white matter

- Hallid alad:
neuronid
- Valged alad:
ühendavad aksonid



Sünapsi väike osa



Kui palju on neuroneid?

- Inimesel ca 90 miljardit neuronit: ca 90.000.000.000
- Ühel neuronil keskmiselt 1000 dendriiti ja 7000 sünapsi
- Võrdluseks: suurimatel protsessoritel on ca 40 miljardit transistori
- Aga: **ühe neuroni analoog on pigem superarvuti**, mitte transistor

C elegans

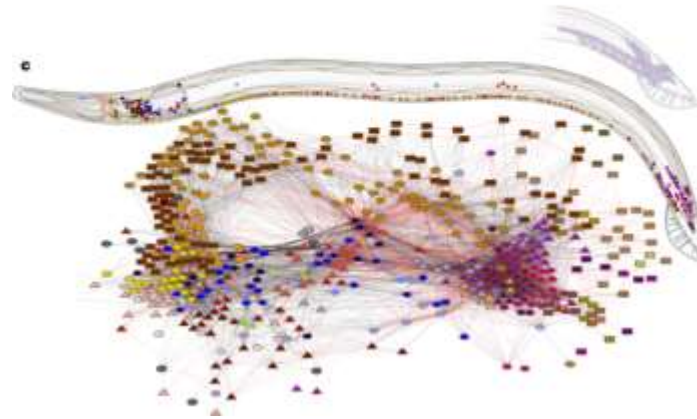
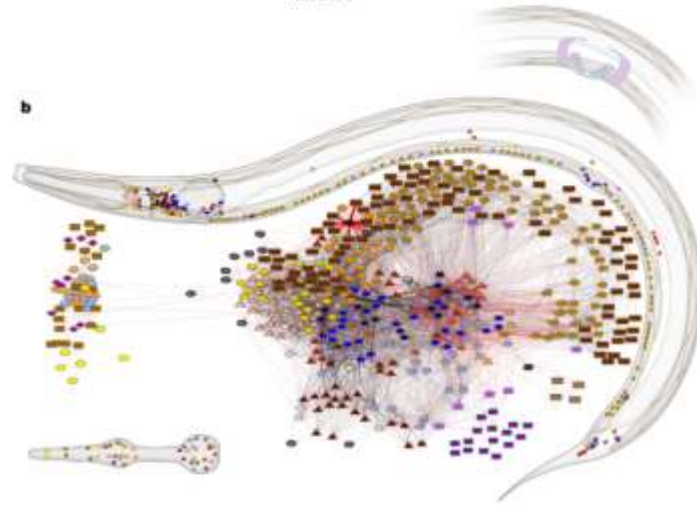
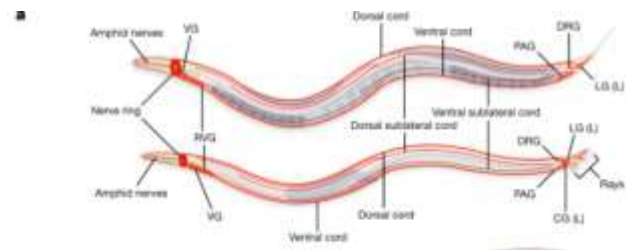
Ca 1 mm pikk väike uss

https://en.wikipedia.org/wiki/Caenorhabditis_elegans

302 neuronit ja 56 gliarakku

Neuronid ja nende ühendused on kaardistatud ja eksisteerivad nende simulaatorid: openworm.org

Sellegipoolest ei saada eriti aru, kuidas see neuronisüsteem ussi juhib



Kuidas neuronid suhtlevad?

Teame hulka eri viise, ja tõenäoliselt on neid veel:

- Elektrisignaalid aksonis: kodeeritud pulsijadadena, mille **ajastus ja sagedus kannab informatsiooni**
- Keemilised signaalid: väga suur hulk erinevaid
- Saadavad teistele neuronitele RNA-d edasi, st programmeerivad neid ümber
- Neuroni elektriväli mõjutab naabreid

Praktiliselt keegi ei saa aru kommunikatsiooni sisust / põhimõtetest.

Eksootiline hüpotees: aju kui kvantarvuti

Rõhuv enamus kvantfüüsikuid ja ajuteadlasi neid oletusi ei usu:

- Beck and Eccles (with Beck being an esteemed theoretical physicist and Eccles winning the 1963 Nobel prize with Hodgkin and Huxley) propose that **consciousness might influence exocytosis**, the process by which cells transport molecules like neurotransmitters across cell membranes, through conscious intentions.
- Penrose's and Hammeroff's Orch-OR theory, which postulates how **quantum states are reduced within the neurons by so-called microtubules**.
- Aga: „Orch-OR has made numerous false biological predictions, and is not an accepted model of brain physiology.“

Aju osad ja funktsioonid

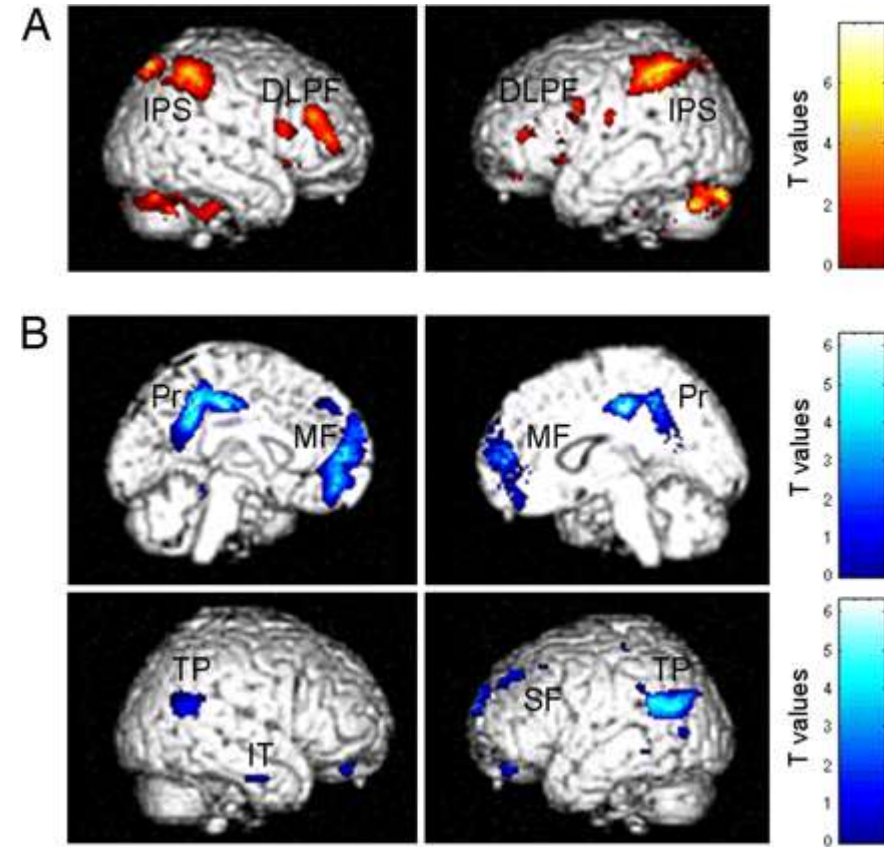
Aju funktsionaalne jaotus

Kuidas seda on peamiselt uuritud:

- Kui mingit ajuosa vigastada, mis funktsioonid kahjustuvad?
- Electroencephalography (EEG): elektroodid pea peal
- fMRI-ga vaadates, mis ajuosades on millal rohkem verd?
- Elektri või magnetiga väljast mõjutades, kus mida umbes mõjutab?
- Elektri või valgusega seest stimuleerides, kus mida umbes mõjutab?
- Kemikaalide söömine või süstimine

fMRI Functional magnetic resonance imaging

- Mõõdab verevoolu ajus
- Aktiivsemad ajuosad saavad rohkem verd
- Vähim mõõdetav ühik ca 1 kuupmillimeeter ja ajaühik paar sekundit
- Teatud hilistumine vere saabumises
- Suudame tuvastada mustreid, mis mingi tegevuse juures ilmnevad, aga need mustrid ei ole aga ajas kuigi püsivad ja eri inimeste jaoks on eri moodi.



Aju funktsionaalne jaotus

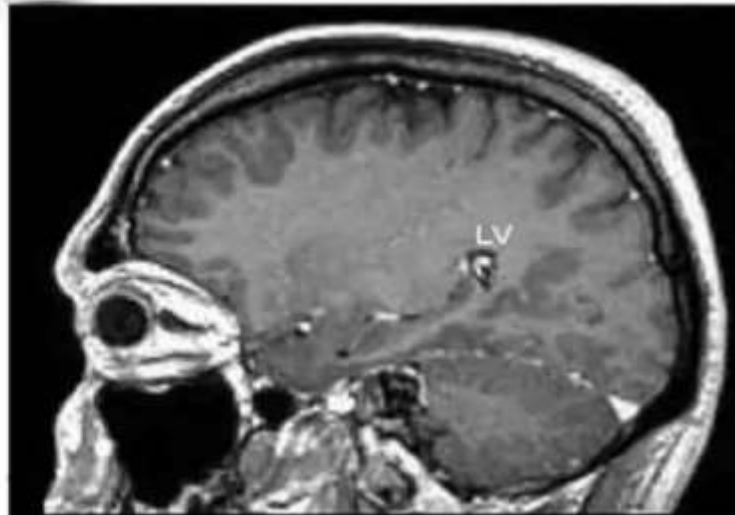
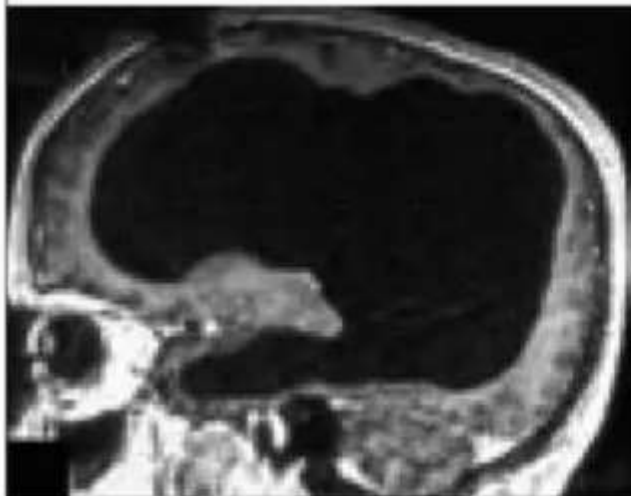
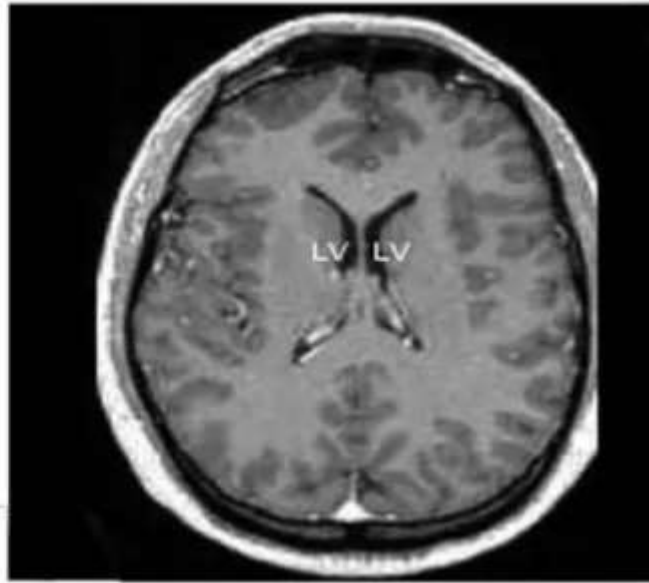
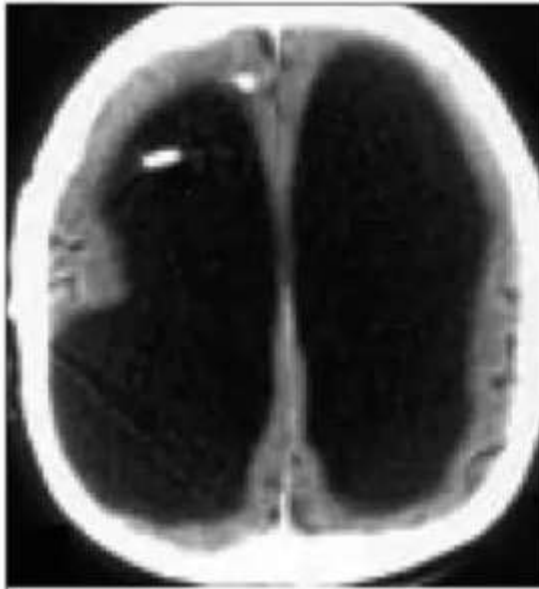
Pane tähele:

- Kogu järgnev pilt on tugev lihtsustus: reaalselt mõjutavad eri aju osad üksteist oluliselt.
- Aju on plastiline: mingi osa kahjustumise järel võtavad teised osad funktsioonid üle.
- See, kuidas mingi funktsioon tegelikult toimib, on üldjuhul praegu pea täiesti arusaamatu.

Äärmusjuhtum nn vesipea sündroomiga

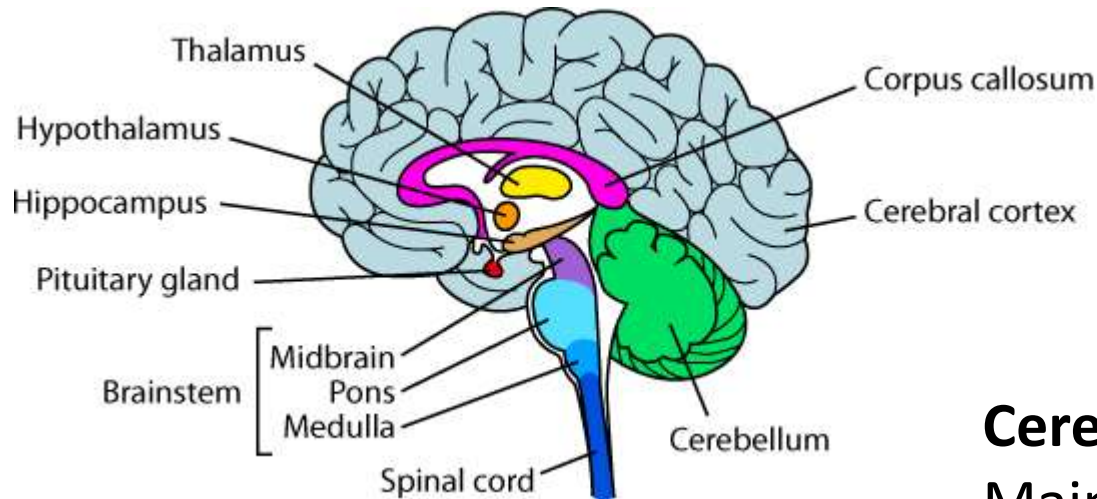
- Wikipedia: „a man whose brain shrank to a thin sheet of tissue, due to a buildup of cerebrospinal fluid in his skull. ...
- Intelligence tests showed the person had an IQ of 75, considered "borderline intellectual functioning", just above what would be officially considered mentally challenged.
- The person was a married father of two children, and worked as a civil servant, leading an at least superficially normal life, despite having enlarged ventricles with a decreased volume of brain tissue.
- "What I find amazing to this day is how the brain can deal with something which you think should not be compatible with life", commented Dr. Max Muenke, a pediatric brain-defect specialist at the National Human Genome Research Institute. "If something happens very slowly over quite some time, maybe over decades, the different parts of the brain take up functions that would normally be done by the part that is pushed to the side.

Äärmusjuhtum vasakul, normaalne paremal



Aju osad: vana värk sees ja ajukoor ümber

Thalamus: sensory integration, motor integration, sleep, consciousness.



Corpus callosum: connecting the left and right brain

Cerebellum: Make smooth, coordinated movements.
Main job: proper movement

Hypothalamus: body temperature, emotions,
hunger, thirst, circadian rhythms

Hippocampus: memories.

Brainstem: breathing, heart rate, blood pressure

Näide: liikumisfunktsioonid laiali eri osades

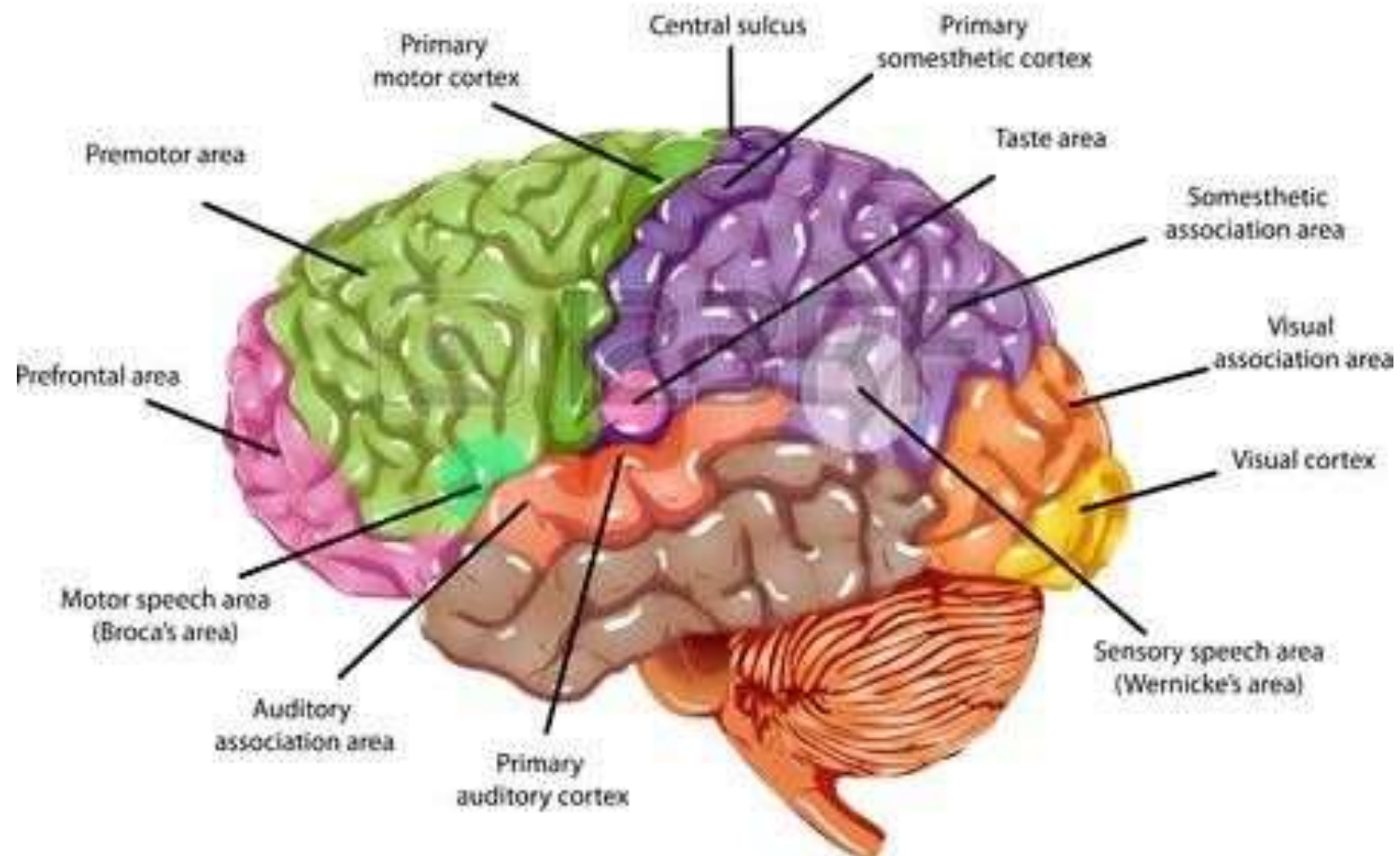
Area	Location	Function
Ventral horn	Spinal cord	Contains motor neurons that directly activate muscles ^[85]
Oculomotor nuclei	Midbrain	Contains motor neurons that directly activate the eye muscles ^[86]
Cerebellum	Hindbrain	Calibrates precision and timing of movements ^[8]
Basal ganglia	Forebrain	Action selection on the basis of motivation ^[87]
Motor cortex	Frontal lobe	Direct cortical activation of spinal motor circuits
Premotor cortex	Frontal lobe	Groups elementary movements into coordinated patterns ^[8]
Supplementary motor area	Frontal lobe	Sequences movements into temporal patterns ^[88]
Prefrontal cortex	Frontal lobe	Planning and other executive functions ^[89]

Ajukoor: kokkuvolditud õhuke kiht

- There are between 14 and 16 billion neurons in the cerebral cortex and it makes up 40 per cent of the brain's mass.
- Wikipedia „The mammalian cerebral cortex, the grey matter encapsulating the white matter, is composed of layers. The human cortex is between **2 and 3 mm thick**. The number of layers is the same in most mammals, but varies throughout the cortex. In the neocortex 6 layers can be recognized.
- The **columnar functional organization** suggests that neurons that are horizontally more than 0.5 mm from each other do not have overlapping sensory receptive fields.
- Various estimates suggest there are 50 to 100 cortical minicolumns in a hypercolumn, each comprising around 80 neurons. Their role is best understood as 'functional units of information processing.'

Ajukoore funktsionaalsed jaotused

Regions of the Human Brain



Mälu liigid (wikipedia)

- [Working memory](#) is the ability of the brain to maintain a temporary representation of information about the task that an animal is currently engaged in. This sort of dynamic memory is thought to be mediated by the formation of [cell assemblies](#)—groups of activated neurons that maintain their activity by constantly stimulating one another.
- [Episodic memory](#) is the ability to remember the details of specific events. This sort of memory can last for a lifetime. Much evidence implicates the hippocampus in playing a crucial role: people with severe damage to the hippocampus sometimes show [amnesia](#), that is, inability to form new long-lasting episodic memories.
- [Semantic memory](#) is the ability to learn facts and relationships. This sort of memory is probably stored largely in the cerebral cortex, mediated by changes in connections between cells that represent specific types of information.

Õppimise liigid (wikipedia)

- [Instrumental learning](#) is the ability for rewards and punishments to modify behavior. It is implemented by a network of brain areas centered on the basal ganglia.
- [Motor learning](#) is the ability to refine patterns of body movement by practicing, or more generally by repetition. A number of brain areas are involved, including the [premotor cortex](#), basal ganglia, and especially the cerebellum, which functions as a large memory bank for microadjustments of the parameters of movement.

Peegelneuronid (mirror neurons)

- Avastus, et hulk meie neuroneid, mis aktiveeruvad mingi tegevuse juures, aktiveeruvad samuti, kui näevad teist ahvi / inimest sama tegevust tegemas.
- Hetkeseis: hulk vastuolulist teooriat peegelneuronite kohta

Ajurakkude süünd täiskasvanud inimesel

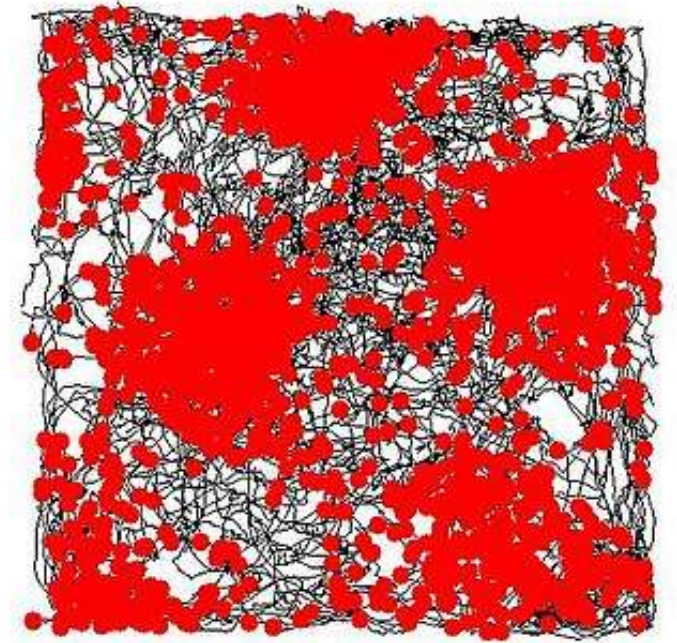
- Klassikaline teooria: ajurakke täiskasvanul ei teki.
- Uuem teooria: ajurakud tekivad ka täiskasvanul.
- Hetkeseis: vastuolulised ja muutlikud seisukohad.

Jennifer Aniston neuron (grandmother neuron)

- „Looking for the areas of the brain that cause epileptic seizures, Quiroga discovered that one subject had **a neuron that steadily fired whenever she was shown a photo of Jennifer Aniston**. It didn't fire for other celebrities, but seemed **linked to the *concept* of Jennifer Aniston**. Another subject had a Halle Berry neuron, and another had one that fired in response to Bill Clinton.“
- Quiroga focuses on neurons in the **hippocampus**, which he believes are associated with many—though not all—the mental processes associated with memory. He notes that the number of hippocampus neurons that seem to be associated with memory is fairly small

Asukoha kaardistamine: grid cells

- Wikipedia: „A **grid cell** is a type of [neuron](#) within the [entorhinal cortex](#) that fires at regular intervals as an animal navigates an open area, allowing it to understand its position in space by storing and integrating information about location, distance, and direction.
- Grid cells have been found in many animals, including [rats](#), [mice](#), [bats](#), [monkeys](#), and humans.“



Wikipedia:

Trajectory of a rat through a square environment is shown in black. Red dots indicate locations at which a particular entorhinal grid cell fired.

Hea teada

Praktiliselt konsensuslik veendumus:

- „**Exercise** stimulates the brain plasticity by stimulating growth of new connections between cells in a wide array of important cortical areas of the brain. Recent research from UCLA demonstrated that exercise increased growth factors in the brain—making it easier for the brain to grow new neuronal connections.“

Taju- ja mõistusteteooriad

Taju kui simulatsioon

Praktiliselt konsensuslik arusaam ajuteaduses:

See, kuidas me maailma näeme, kuuleme jne, on **aju konstrueeritud simulatsioon**. Füüsilised sensor-neuronid on allikas, mille põhjal looma aju konstrueerib simulatsiooni, mis võiks enamvähem vastata reaalsusele.

Asjad, mida me sensorrakkudega ei tunneta, pannakse simulatsioonis lihtsalt „mõistliku oletusena“ sinna paika.

„Merest väljumise“ mõistuse evolutsiooniteooria

Idee:

- Meres sügaval vee all ei näe eriti kaugemale. Seega ei saa ette planeerida, ainult kiirelt reageerida.
- Maa peale tulles tekkis võime näha kaugemale. Seega sai ette planeerida: kuhu minna, kuidas saaki kätte saada või vastupidi, kuhu põgeneda jne.

Kasutajaliidese teooria (MUI theory of mind)

- MUI theory states that "**perceptual experiences do not match or approximate properties of the objective world, but instead provide a simplified, species-specific, user interface to that world.**"
- Hoffman argues that conscious beings have not evolved to perceive the world as it actually is but **have evolved to perceive the world in a way that maximizes "fitness payoffs"**.
- Hoffman: „**Natural Selection Drives True Perception To Swift Extinction**“

Kasutajaliidese teooria (MUI theory of mind)

- Hoffman uses the **metaphor of a computer desktop and icons** - the icons of a computer desktop provide a functional interface so that the user does not have to deal with the underlying programming and electronics in order to use the computer efficiently.
- Hoffman has said that some form of reality may exist, but may be completely different from the reality our brains model and perceive. **Reality may not be made of space time and physical objects.**

Teadvuseteeooriad

David Chalmers ja „hard problem of consciousness“

Vastuolusid ja vaidlusi tekitav D. Chalmersi mõtteliin:

- The „easy“ problems may include **how sensory systems work, how such data is processed in the brain**, how that data influences behaviour or verbal reports, the neural basis of thought and emotion, and so on.
- The „hard“ problem of consciousness is the problem of explaining why and how we phenomenal experiences. That is to say, **why do we have personal, first-person experiences**, often described as experiences that feel "like something."

Teadvuseteooriate kaks põhitüüpi

- Mehhanismide seletamine, mis võiksid olla teadvuse-süsteemi osad
 - <https://plato.stanford.edu/entries/consciousness-neuroscience/>
 - Puhtfüsioloogilised
 - Neuroloogilised
 - Simulatsioonid jms
 - ...
- Teadvuse olemuse oletused
 - Emergentsuse eri variandid: sobivad normaalfüüsikaga
 - Panpsühhism ja integrated information theory (ei sobi normaalfüüsikaga)
 - Raadio-teooria
 - ...

Global workspace theory

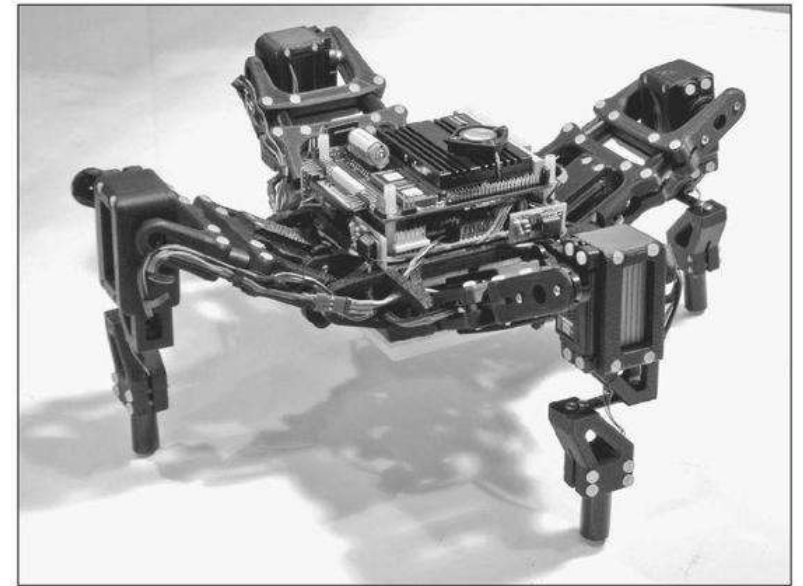
https://en.wikipedia.org/wiki/Global_workspace_theory

https://en.wikipedia.org/wiki/Dehaene%E2%80%93Changeux_model

“GWT involves a fleeting memory with a duration of a few seconds (much shorter than the 10–30 seconds of classical working memory). GWT contents are proposed[citation needed] to correspond to what we are conscious of, and are broadcast to a multitude of unconscious cognitive brain processes, which may be called receiving processes. Other unconscious processes, operating in parallel with limited communication between them, can form coalitions which can act as input processes to the global workspace.”

Metzingeri teooria

- Robot või organism peab sisaldama iseenda mudelit, et simuleerida, mis juhtub, kui ta liigutab või üldse teeb midagi.
- „In this book he argues that no such things as [selves](#) exist in the world: nobody ever had or was a self. All that exists are [phenomenal selves](#), as they appear in conscious experience. He argues that the phenomenal self, however, is not a thing but an ongoing process; it is the content of a "transparent [self-model](#)."



Graziano teadvuseteooria põhipunkt

First, when a person asserts “I am conscious of X,” whatever X may be, whether a color, a tactile sensation, a thought, or an emotion, the assertion depends on some system in the brain that must have computed the information, otherwise the information would be unavailable for report. Not only the information represented by X, visual information or auditory information for example, but also the essence of consciousness itself, the inner feeling attached to X, must be information or we would be unable to say that we have it. In this hypothesis, consciousness is not an emergent property, or a metaphysical emanation, but is **itself information computed by an expert system.**

Graziano teadvuseteooria punkt 2

Second, people routinely compute the state of awareness of other people. A fundamental part of social intelligence is the ability to compute information of the type, “Bill is aware of X.” In the present proposal, the awareness we attribute to another person is our reconstruction of that person’s attention. **This social capability to reconstruct other people’s attentional state is probably dependant on a specific network of brain areas that evolved to process social information,** though the exact neural instantiation of social intelligence is still in debate

Graziano teadvuseteooria punkt 3

Third, in the present hypothesis, **the same machinery that computes socially relevant information of the type, “Bill is aware of X,” also computes information of the type, “I am aware of X.”** When we introspect about our own awareness, or make decisions about the presence or absence of our own awareness of this or that item, we rely on the same circuitry whose expertise is to compute information about other people’s awareness.

Graziano teadvuseteooria punkt 4

Fourth, awareness is best described as a perceptual model. **It is not merely a cognitive or semantic proposition about ourselves that we can verbalize. Instead it is a rich informational model that includes, among other computed properties, a spatial structure.** A commonly overlooked or entirely ignored component of social perception is spatial localization. Social perception is not merely about constructing a model of the thoughts and emotions of another person, but also about binding those mental attributes to a location.

Graziano teadvuseteooria punkt 5

Fifth, because we have more complete and more continuous data on ourselves, **the perceptual model of our own awareness is more detailed and closer to detection threshold** than our perceptual models of other people's awareness.

Äärmusteooria: panpsühhism

- Panpsühhismi seisukohalt on **kõigel teadvus**: ka lillel, kivil, liivateral, aatomil, elektronil.
- Lihtsamatel süsteemidel on lihtsalt **vähem teadvust**.
- Raske küsimus panpsühhismi jaoks: kui süsteemi osadel on omad teadvused, siis kas kõigil osade kombinatsioonidel on ka erinevad teadvused?

Näiteks: olgu meil kolm kokkukleepunud liivatera 1,2,3: kas omad teadvused on kõigil hulkadel $\{1\}, \{2\}, \{3\}, \{1,2\}, \{1,3\}, \{2,3\}, \{1,2,3\}$

Integrated information theory

Panpsühhismi spetsiifiline variant

Giulio Tononi , Christof Koch

Üritab mõõta teadvuse mahtu (a la väiksematel süsteemidel vähem, suurematel rohkem)

https://en.wikipedia.org/wiki/Integrated_information_theory